Performance Evaluation and Improvement of a Dual-frequency Laser Interferometer for Nano Positioning Stage

Chen Yonghui, Chi Feng, Zhang Xiaowen, Zhang Zhiping, Cheng Jianrui, Xiao Pengfei

Shanghai Micro Electronics Equipment Co., Ltd. (China)

chenyh@smee.com.cn

Abstract

With advances of technologies in fields of IC manufacturing, positioning and measuring accuracy of ultra-precision machining and precision instruments is getting higher and higher. The combination of high resolution and outstanding accuracy has made high performance laser interferometer an ideal choice for IC photolithography.

But testing and evaluation of an interferometer system is very difficult, because it can be easily affected by pressure, vibration and temperature. How to analyze a system error, and which error sources can be minimized or eliminated are discussed. A method to test and evaluate the performance of interferometer system is proposed. To conduct the test and evaluation, an experiment system of macro-micro actuators based long stroke nano-positioning stage is provided, and it is made up of a coarse stage covering long range up to an accuracy of a few micrometers, as well as a fine stage covering small range at nano-accuracy. And with an appropriate dual servo control loop algorithm implemented to link the stages, it can give nanometer accuracy over the long range of motion. Based on that, corresponding experiments under standstill circumstance, uniform motion as well as long time evaluation are carried out, and the correctness and effectiveness of the high performance interferometer research are validated.

1 Introduction

With progress of techniques in fields of IC manufacturing, line width shrinks, overlay gets tighter and tighter, and wafer stage is required to move more quickly, steadily and accurately. Accordingly, air-bearing or magnetically levitated actuators and interferometer measurement become ideal for IC photolithography.

To get satisfied performance, wafer stage needs excellent interferometer to achieve good positioning accuracy. However, test and evaluation of an interferometer system is very difficult, since it is easily affected by pressure, vibration, and temperature, installation and the shifting of subjects to be observed.

There are three categories of measurement errors in the test of an interferometer system, such as installation errors, instrument errors and environment errors. Environment error is subjected to pressure, humidity and temperature. Experiments show it is a key factor affecting measurement accuracy, and must be controlled carefully. Installation error includes abbe and cosine error, it can be corrected by metrology. Instrument error is subjected to device performance; it can not be eliminated, but only minimized with application of better device. Theoretically, evaluation on a measurement system needs higher accuracy than itself. However, there are no other devices that achieve better accuracy than an interferometer system of such a wide measurement range.

It is known that bad instrument error causes bad measurement error. In a closed loop servo system, bad measurement performance causes bad servo performance. Therefore, if a servo system using an interferometer as feedback works well enough, the performance of the interferometer system must be satisfactory. In this paper, this idea has been explored with experiment results.

2 Positioning Stage and Environment System

An experiment system of long stroke nano-positioning stage based on macro-micro actuators is provided to test and evaluate the performance of interferometer. A coarse stage covers long range up to an accuracy of a few micrometers, and a fine stage covers the small range of nanometer accuracy, and with an appropriate dual servo control loop algorithm implemented to link the stages and gives nanometer accuracy over the long range of motion. Air-bearing systems are used in both long stroke motor and moving stage to improve the servo performance. To compensate abbe error, cosine error, and environment error, special metrology algorithm is designed and added in the control board.

Since interferometer accuracy is subjected to environment conditions, careful control is important to ensure stable pressure, humidity, temperature, and vibration must also be isolated.

3 Performance Evaluation

The measurement system, which is developed by SMEE for lithography's nanometer positioning with 0.31nm resolution dual-frequency laser interferometer, is evaluated under conditions of standstill and uniform motion. Moreover, to evaluate its reliability under long time conditions, position error is continuously sampled in one hour duration.

3.1 Standstill Evaluation

Standstill evaluation means the stage is controlled to stand at a certain position, surely with interferometer feedback. Since the vibrations are effectively isolated, variation of the position error reflects the jitter degree of the interferometer system. Experiment results are as follows (position unit: um):

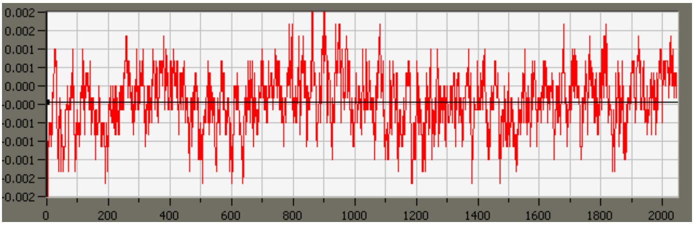

Figure 1: Standstill Test and Evaluation

Experiment results show servo performance is satisfactory. And the statistical variation of position error is only 0.83nm, which indicates interferometer performs very well under standstill conditions.

3.2 Uniform Motion Evaluation

Uniform motion evaluation means the stage is controlled to move at a steady velocity, and position sampling is performed during the period of uniform motion. Uniformity of the movement is analyzed, and the experiment results are as follows:

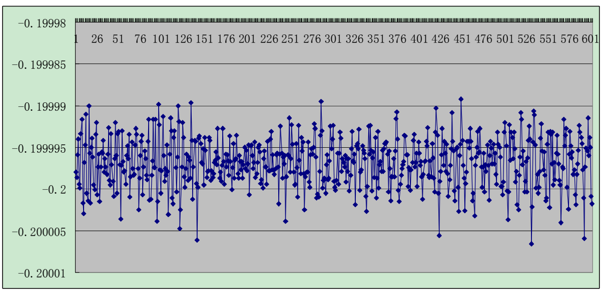

Figure 2: Uniform Motion Evaluation

Experiment results show that the movement uniformity is fairly good, and the velocity fluctuation is only up to 0.0015%, which indicates that interferometer system performs very well under such a velocity.

3.3 Long Time Evaluation

Long time evaluation means the stage is controlled to stand at a certain position, surely with interferometer feedback, and position error is continuously sampled in one hour duration to test the reliability of the interferometer system. Experiment results are as follows:

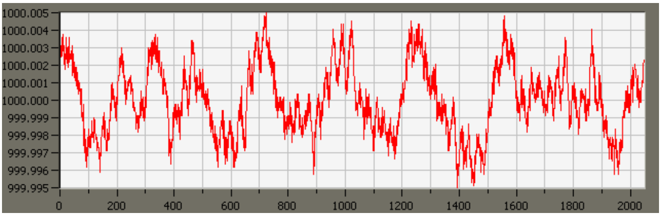

Figure 3: Long Time Evaluation

Experiment results show the servo performance is satisfactory, and the statistical variation of position error is only 1.89nm, which proves the interferometer system reliably works under long time conditions.

4 Conclusion

Performance of the interferometer system is tested and evaluated through a nano positioning stage. The idea is that if a servo system using interferometer as feedback works well enough, the performance of the interferometer system must be satisfactory. Experiment results testify this evaluation is trustworthy.

But this method is only limited to qualitative, quantitative evaluation, and some other effective ways are expected to be discussed. Moreover, to get satisfied evaluation results, good servo system design and special environment control are indispensable, sometimes even become critical issues.